10/577583
IAP12 Rec'd PCT/PTO 27 APR 2006

DESCRIPTION

The present invention relates to a pneumatic plate element as recited in the preamble of claim 1.

Pneumatic components or supports, consisting of an inflatable hollow body and separate elements for absorbing compression and tensile forces, are known. The most closely related description of the art is represented in WO 01/73425 (D1).

In D1, the hollow body that is subjected to pressure loading serves primarily to stabilize the pressure element and to prevent it from buckling. To this end, the pressure element is attached non-positively to the membrane of the hollow body over some or all of its length.

In addition, the height of the support elements is defined by the hollow body, and the tensile and compressive elements are also located separately from each other. The design disclosed in document D1 enables very light but rigid and pneumatic structures to be produced that are capable of bearing considerable loads. However, the pneumatic element described in the preceding has a number of drawbacks. The tensile forces in the membrane of the hollow body may exert high stresses on the area of the attachment between the membrane and the pressure element with regard to tear strength. Moreover, the structural design of this attachment is very complex and therefore very expensive. The hollow body cross sections of the components that are possible are essentially limited to circles. The support element disclosed in D1 is essentially a one-dimensional support structure. For roof structures

covering large surface areas, that is to say essentially two-dimensional support structures, an extra roof membrane is required and must be stretched between or over support elements. The hollow body also has a large membrane surface area relative to the area it covers (the following formula applies for circular cross sections: circumference/diameter = pi, i.e. approx. 3.14 m^2 membrane per m^2 of covered area), which again leads to relatively high costs.

The object of the present invention is to provide a pneumatic support structure element that eliminates these disadvantages of the known constructions and which may be constructed as a large-area, two-dimensional support structure.

The solution to this object is reflected in the characterising part of claim 1 with respect to the main features thereof, and in the subsequent claims with respect to additional advantageous embodiments.

The object of the invention will be explained in greater detail with reference to the accompanying drawing. In the drawing:

Figure 1a,b shows a longitudinal and cross section of a first embodiment of a pneumatic plate,

Figure 2 illustrates the static principle with reference to a beam in side view,

Figures 3-5 show various arrangement options for the prestressed tension elements in side view,

Figures 6-8 show a longitudinal section view of various methods of passing the pre-stressed tension elements through the membrane of the hollow body in gas-impermeable manner,

Figures 9,10 show longitudinal section views of two embodiments of a method for passing the prestressed tension elements through the hollow body,

Figures 11-13 show cross section views of various arrangement options for the prestressed tension elements,

Figures 14-17 show longitudinal section views of plate elements in various shape variants,

Figure 18 shows a longitudinal section view of an embodiment of a plate element whose shape differs from that of the hollow body,

Figure 19 shows a longitudinal section view of an embodiment of a plate element having several hollow bodies aligned transversely to the direction of the compression/tension elements,

Figure 20 shows a longitudinal section view of an embodiment of a separable plate element in the separated condition,

Figure 21 shows a longitudinal section view of an embodiment of a plate element with in the

separated condition,

Figure 22 shows an isometric view of an embodiment with pressure plates with variable cross section,

Figure 23 shows an isometric view of an embodiment with transverse reinforcements of the pressure elements,

Figure 24 shows an isometric view of an embodiment with a single pressure plate with large cutouts,

Figure 25 shows an isometric view of an embodiment of a plate element with compression/tension elements arranged in two directions,

Figure 26 shows an isometric view of an embodiment of a plate element with a polygonal arrangement of the compression/tension elements,

Figure 27 shows an isometric view of an embodiment of a roof consisting of a plate element,

Figure 28 shows an aerial view of several polygonal plate elements,

Figure 29 shows an isometric view of a combination of several rectangular plate elements,

Figure 30 shows a schematic isometric view of two rectangular plate elements,

Figure 31a,b shows schematic, exploded isometric and plan view of an embodiment of a plate element with compression/tension lattices,

Figure 32 shows a plan view of a second embodiment of a plate element with compression/tension lattices.

Figs. 1a, b show a first embodiment of a pneumatic plate element 1. Fig. 1a shows pneumatic plate element 1 in longitudinal section BB, Fig. 1b in cross section AA. Two compression/tension elements are attached non-positively to each other by their ends and enclose a hollow body 3, which is made from a flexible membrane 9 and is capable of absorbing pressure. Because of the low tensile stresses exerted on it, membrane 9 may be made for example from highly transparent, very thin foils of partially fluorinated thermoplastic plastics (for example ETFE, ethylene-tetrafluoroethylene).

Compression/tension elements 2 are suitable for absorbing both tensile and compressive forces and may be made for example from wood or steel. The two compression/tension elements 2 are connected non-positively to each other at for example regular intervals a via tension elements 4 that serve purely to absorb tensile forces. These tension elements 4 pass through hollow body 3. They are situated for example in gas-impermeable channels 5 that traverse hollow body 3. Hollow body 3 is not attached to compression/tension elements 2. Pneumatic plate element 1 is essentially supported on a support 17 in the area of the non-positive attachment of compression/tension elements 2.

If hollow body 3 is subjected to pressure, compression/tension elements 2 are forced apart and tension elements 4 are prestressed. If plate element 1 is loaded transversely, compression forces are exerted on the compression/tension element 2 located above hollow body 3, and tensile forces are exerted on the compression/tension 2 element 2 that passes through hollow body 3. The compression/tension element 2 that is subjected to compression tends to buckle under load. A connector 6 between the compression/tension elements 2 and the prestressed tensile elements 4 acts as an intermediate support 18 for compression/tension element 2 and in static terms causes the compression/tension element 2 that is loaded with pressure to act as a compression strut or a pressure plate with rigid or elastic intermediate supports 18 according to the prestressing of tensile elements 4 and depending on the magnitude of transversely acting force F. The essentially equivalent situation in static terms is illustrated in Fig. 2 with the example of a beam that is supported at intervals on multiple rigid intermediate supports 18 between the two supports 17.

For purposes of simplicity, in the following text, single-sided load situations, for example due to gravitational forces F, will be assumed for pneumatic plate elements 1. Accordingly, the upper compression/tension elements 2 that are generally subjected to compression loads will be designated compression elements 7, and the lower compression/tension elements 2 that are generally subjected to tensile loads will be designated tension elements 8. In cases in which this one-sided load situation is never reversed, the compression/tension element 2 that is always

subjected to tension may of course also be constructed as a pure tension element 8, which is and may be subjected exclusively to tensile loading. For example, a rope or cable may be used for this. In the case of roofs, however, wind drag may cause the weight of the roof construction to be overcompensated, and thus cause compression forces to be exerted on the lower compression/tension elements 2 as well. Fluctuating compressive or tensile loads on compression/tension elements 2 also arise in plate elements that are erected vertically, for example when they are used as walls.

While the prestressing force of vertical tensile element 4 is greater than the stabilising force that is required to prevent compression element 7 from buckling, connections 6 operate as fictitious fixed intermediate supports. Deflections only occur at point of connections 6 when the stabilising force required exceeds the prestressing force of prestressed tensile element 4. Overpressure p in hollow body 3, distance a between prestressed tensile elements 4 and the width and height of compression element 7 are selected for a defined load of plate element 1 such that the prestressing force is always significantly greater than the stabilising force required to prevent buckling. In this context, the smaller the distances a, the smaller the prestressing force from prestressed tensile elements 4 for stabilising compression element 7. As distances a increase, this stabilising prestressing force also becomes larger, but at the same time the unstabilised, unsupported length in compression element 7 also becomes larger, and this may cause buckling under even relatively small axial compression forces acting on compression element 7. The best distribution and number of prestressed tensile

elements 4 with regard to stability and weight may be optimised arithmetically on a case by case basis.

Figs. 3-5 show a number of different variants in the way tensile elements 4 may be tightened between compression/tension elements 2. Hollow body 3 is now shown in these figures. Fig. 3 shows various inclinations of tensile elements 4, and several tensile elements 4 that are attached to compression elements 7 essentially at the same point via a connection 6. An arrangement of prestressed tensile elements 4 is shown in Fig. 4 with a vertical plane of symmetry, and in Fig. 5 with a vertical and a horizontal plane of symmetry. The planes of symmetry are indicated by dash-dotted lines.

Figs. 6-8 show various exemplary methods for solving the detail of the connection between membrane 9 and the prestressed tensile element 4. Figs. 6 and 7 show variants in which this connection is realised non-positively in the axial direction of tensile element 4. In Fig. 6 the connection is created by bonding or welding, and in Fig. 7 via a connecting element 10 that connects prestressed tensile element 4 with compression/tension element 2 and at the same time non-positively seals the passthrough through membrane 9 in gas-impermeable manner. Connecting element 10 may be made for example from extruded PVC or metal.

Fig. 8 shows a variant having a gas-impermeable opening in membrane 9 that is movable along tensile element 4. An eyelet 11 is incorporated in membrane 9 and the point at which tensile element 4 passes through the membrane is sealed gas-tight manner via a seal 12.

The longitudinal section through a plate element 1 in the area of a prestressed tensile element 4 is shown in Fig. 9. This is the same variant for passing these tensile elements 4 through hollow body 3 as in Figs. 1a,b. A channel 5 is incorporated in hollow body 3, and tensile element 4 is drawn through this.

Fig. 10 is a detailed view in longitudinal section of such a passthrough with channel 5. And endpiece 13 is furnished with an opening to accommodate a tensile element 4. Endpiece 13 may also be produced inexpensively from extruded PVC. It is also equipped with a device for clamping membrane 9 in gas-tight manner. It is also possible to bond endpiece 13 to membrane 9 by adhesion or welding. In this case, endpiece 13 does not need to include a membrane clamping device. A tube 14 placed over two endpieces 13 forms a channel 5, in which ambient pressure exists. Someone who is skilled in the art will be aware of other possible arrangements using an endpiece 13 and a membrane clamping device with an attached tube 19, for example a hose 14 slipped over the opening. The two endpieces 13 that are connected by a tube 19 or a hose 14 are or such size that they are able to be inserted into hollow body 3 through an aperture in membrane 9 and may be attached to membrane 9 from the inside.

Figs. 11-13 show cross sections of various alternatives for arranging prestressed tensile elements 4. As shown in Fig. 11, it is also possible for more than one prestressed tensile element 4 to be passed through hollow body 3 side by side. Prestressed tensile elements 4 may also be used to connect compression/tension elements 2 outside hollow body 3 (Fig. 12, Fig. 13). If compression/tension elements 2 are

flat, it is also conceivable and consistent with the invention to arrange several tubular hollow bodies 3 side by side between compression/tension elements 2 and in the direction of compression/tension elements 2 (Fig. 13).

Figs. 14-17 show several possible longitudinal section shapes for pneumatic plate elements 1, wherein only compression/tension elements 2 and tensile elements 4 are shown schematically. Fig. 14 shows an essentially rectangular longitudinal section, in which the two compression/tension elements 2 run parallel to each other for the most part. Fig. 15 shows a symmetrically lenticular longitudinal section, and Fig. 16 an asymmetrically lenticular longitudinal section. Arched longitudinal sections, as shown in Fig. 17, are also possible.

Fig. 18 shows an embodiment of a pneumatic plate element 1 in which the shape of hollow body 3 and the cavity defined by compression/tension elements 2 differ in the longitudinal section. Hollow body 3 may also occupy only a part of this cavity.

Fig. 19 shows a plate element 1 with multiple tubular hollow bodies 3 which, unlike the embodiment shown in Fig. 13, are arranged transversely to the direction of compression/tension elements 2.
The plate element 1 shown in Fig. 20 is divided into several segments in the direction of compression/tension elements 2. The segments are shown separated in longitudinal section. The individual segments are connected to form a complete compression/tension element 2 via non-positive, flexurally resistant connections with the aid of connecting members 20. The separability yields advantages

in terms of transporting the elements. In general, it may be noted that all compression/tension elements 2 in the preceding and following examples may be constructed so as to be separable.

The following figures show a few possible embodiments of pneumatic plate elements 1 or combinations of plate elements 1. These examples reveal a further advantage compared to the related art, in that the carriers do not have to be essentially tubular, the disclosed construction method with prestressed vertical tensile elements 4 allows greater freedom of design and variation in shape. In particular, it enables two-dimensional, plate-shaped carriers to be produced.

Fig. 21 is a schematic, isometric representation of a pneumatic plate element 1 having compression/tension elements 2 extending parallel in one direction. The compression/tension elements 2 form pairs, in which one compression/tension element 2 extends over hollow body 3, and one compression/tension elements 2 extends below hollow body 3. The single hollow body creates the prestress for tensile elements 4 on three pairs of compression/tension elements 2. Only compression/tension elements 2 and hollow body 3, which is illustrated by additional lines, are shown in the schematic diagram. The prestressed tensile elements 4 extend between the paired compression/tension elements 2, but they are not shown in this or the following figures.

In Fig. 22, three pressure plates with a cross section that becomes narrower towards the middle are used as pressure elements 7. At their supported ends, the three pressure plates form an unbroken, full-length edge.

In Fig. 23, pressure elements 7 are also reinforced with transverse struts 15 and wind braces 16. And finally Fig. 24 shows yet another embodiment that includes a single, plate-shaped pressure element 7 with large cutouts. The cutouts may be provided in any size or shape, in any pattern, and in any number, and serve primarily to reduce weight. It is clearly shown in this embodiment that compression/tension elements 2 do not necessarily have to be paired. A single plate-shaped pressure element 7 may be connected at its ends with several tension elements 8 or compression/tension elements 2.

Figs. 25-27 show embodiments of pneumatic plate elements 1 with compression/tension elements 2 that are arranged in two or more directions. In Fig. 25, four pairs of compression/tension elements 2 form a cross that is filled out by hollow body 3 to form an octagonal surface. In this case, compression/tension elements 2 are arranged orthogonally with each other.

Fig. 26 shows an example of a plate element 1 with a polygonal plan. The three pairs of compression/tension elements 2 are arranged in a star formation. The angles between the pairs of compression/tension elements 2 may be chosen at will. Also, compression/tension elements 2 may intersect at different and multiple points.

Fig. 27 shows a further embodiment of a plate element 1 with compression/tension elements 2, arranged in two directions. Three contiguous crosses, each formed from two pairs of compression/tension elements 2, and a hollow body 3 form a large, rectangular plate element 1. Each pressure

element 7 must be supported on a support 17 at both ends. In the case of a roof, the function of support 17 may be served by columns, for example.

Fig. 28 shows in an aerial view how plate elements 1 with a hexagonal plan may be combined in any manner to form larger, contiguous surfaces.

Further options for combining plate elements 1 to form larger area structures based on rectangular area structures are shown in Figs. 29, 30. Fig. 29 is an isometric diagram of an area consisting of six combined plate elements 1 with compression/tension elements 2 arranged in two directions. In Fig. 30, the same area is shown diagrammatically with the compression/tension elements 2 and formed by two plate elements 1 with compression/tension elements 2 arranged in four directions.

In the case of roofs, for example, the insulating property of plate element 1 may be increased substantially due to the reduction in convective heat transfer brought about by one or more membranes that are introduced horizontally in hollow body 3 and at all events positioned using textile crosspieces. For safety purposes, a large hollow body 3 may be divided into several chambers that are isolated in air-tight manner from each other, so that if the membrane is damaged pressure is not lost in the entire hollow body 3, and the failure only affects a part of the chambers. Because of the small pressures required, less than 100 mbar, hollow bodies 3 that extend more than 10 m may also be loaded with compressed air using a fan instead of a compressor.

In Fig. 31a,b shows a further diagrammatic illustration of an embodiment of the basic inventive principle described in the preceding. Compression/tension elements 2 may be constructed as two-dimensional, polygonal lattices, which in turn consist of multiple element sections 21 joined via connectors 22 and form a pressure/tension lattice 23. Two such pressure/tension lattices 23 enclose one or more hollow bodies 3 and are connected via tensile elements 4. At the connections 22 where element sections 2 meet, the two pressure/tension lattices 23 are connected with at least one tensile element 4, unless element sections 21 from different pressure/tension lattices 23 meet directly, as happened for example at the edge of plate element 1 or in the case of connections 22 that rest on supports 17 inside the area of plate element 1. Additional tensile elements 4 may also be attached along the length of element sections 21. For example, instead of four continuous compression/tension elements 2 that are connected to each other, the plate element in Fig. 25 might also be constructed from twelve element sections 21 that form a pressure/tension lattice with four connections 22. Depending on the load type, connections 22 must be capable of absorbing and transferring compression and/or tension loads. Connection 22 may be constructed for example from an additional connecting element, with articulations, also from a rigid, non-separable connection for example by welding or adhesive bonding.

Fig. 31a shows an isometric diagram of plate element 1, wherein upper pressure/tension lattice 23 is shown separated from the lower lattice for clarity, hollow body 3 has been omitted entirely, and the course of tensile members 4 is indicated with dotted lines for exemplary

purposes at just a few connections 22.

Fig. 31b shows a schematic plan view of the embodiment of Fig. 31a.

Another possible method for dividing a pressure/tension element into several element sections 21 is shown in Fig. 32. In Fig. 32, it is conceivable that besides the supports 17 at the edge of pressure/tension lattice 23, one or more additional supports 17 are present inside the area of plate element 1. If an additional support 17 is provided in the middle of pressure/tension lattice 23, hollow body 3 is annular, or essentially toroidal, and the upper and lower pressure/tension lattices 23 meet at support 17 or are connected via a vertical pressure element.

Pneumatic carrier structures may be constructed from multiple plate elements 1. A plate element 1 with pressure/tension lattices 23 may have practically any two-dimensional shape. Particularly when several plate elements 1 are combined, the architect or engineer has an extremely high degree of design freedom.

The shape and size of the mesh in pressure/tension lattices 23 may be adapted to the actual progress of stress in plate element 1. Element sections 21 may be of various lengths, shapes and strengths, and may be constructed from various materials. For example, greater stresses may occur at the edge of plate element 1, close to supports 17, than towards the middle of the area of the pressure/tension lattice 23.

The pneumatic plate elements 1 according to the invention with pressure/tension lattices 23 are particularly suitable

for loads that are distributed in two dimensions, such as occur particularly for example as a result of snow and wind loads on roof construction.

Of course, such plate elements 1 may also take many other forms, and these in turn may be combined in many different ways to form larger two-dimensional structures. On the basis of the fundamental principle illustrated in Fig. 1, compression/tension elements 2 may be distributed in any direction and number over the surface of the at least one hollow body 3, and even the one or more hollow bodies 3 may have any shape.

When plate elements 1 are used as floating, rigid containers, hollow bodies 3 may also be filled with a liquid, for example petrol or oil. These containers may be used as stationary tanks, or they are also highly suitable for towing by ships due to their rigidity.

On the other hand, if hollow bodies 3 are loaded with a gas that is lighter than air, the weight of the plate element 1 may be reduced so that the entire construction floats in the air and static buoyancy ensues.